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Advanced Composite Aileron For L-1011 Transport Aircraft

DLR 003

QUARTERLY TECHNICAL REPORT – NO. 2

This report is for the period 22 December 1973 through 24 March 1978

Lockheed Corporation
Lockheed-California Company
Post Office Box 551
Burbank, California 91520

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Approved By: ______________

F.C. English
Program Manager

14 April 1978

Prepared for Langley Research Center

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FOREWORD

This report was prepared by the Lockheed-California Company, Lockheed Corporation, Burbank, California, under contract NAS1-15069. It is the second quarterly technical report covering work completed between 22 December 1977 and 24 March 1978. The program is sponsored by the National Aeronautics and Space Administration (NASA), Langley Research Center. The Program Manager for Lockheed is Mr. Fred C. English. Mr. Louis F. Vosteen is Project Manager for NASA, Langley. The Technical Representative for NASA, Langley is Mr. Herman L. Bohon.

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SUMMARY

The activities performed in this reporting period and documented in this report are associated with Task I - Engineering Development, and Task II - Design and Analysis of the Advanced Composite Aileron (ACA) program. Task I activities included the completion of design assessment and material evaluation. The detail design of the aileron has been initiated as part of Task II.

Design and evaluation of alternate concepts for the major subcomponents of the ACA was completed. From this array of subcomponents aileron assemblies were formulated and evaluated. Based on these analyses a multirib assembly with graphite tape/syntactic core covers, a graphite tape front spar, and a graphite fabric ribs was selected for development in the remainder of the ACA program. A weight savings of 29.1% (40.8 pounds per aileron) is currently being predicted for the ACA. Engineering cost analyses indicate that the production cost of the ACA will be 7.3% less than the current aluminum aileron.

Fabrication, machining, and testing of the material evaluation specimens for the resin screening program was completed at Lockheed-California Company and Avco. These test results lead to the selection of Narmco 5208 resin for the ACA.

Task II activities initiated during this reporting quarter include the detail design of the ACA, construction of a three-dimensional finite element model for structural analysis, and formulation of detail plans for material verification and process development.

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SECTION 1

INTRODUCTION

The broad objective of NASA's Aircraft Energy Efficiency (ACEE) Composite Structures Program is to accelerate the use of composite materials in aircraft structures by developing technology for early introduction of structures made of these materials into commercial transport aircraft. This program, one of several which are collectively aimed toward accomplishing the broad objective, has the specific goal to demonstrate the weight and cost-saving potential of secondary structures constructed of advanced composite materials. The secondary structure selected for the program is the inboard aileron of the Lockheed L-1011 aircraft.

The scope of this program is to design, fabricate, qualify, and certificate a composite inboard aileron; to test selected subcomponents to verify the design; to fabricate and test two ground test articles; to fabricate and install ten shipsets of inboard ailerons; and to gather flight service data on the ten shipsets of composite ailerons.

The Lockheed-California Company is teamed with Avco Aerostructures Division of Avco Corporation. Lockheed will design the aileron, conduct the materials, concept verification, and ground tests, and evaluate in-flight service experience. Avco will develop manufacturing processes, fabricate test specimens, and fabricate the ground test and flight articles.

As shown on the master schedule, Figure 1-1, the program will be conducted in six nonsequential tasks. Task I, Engineering Development, and Task II, Design and Analysis, are the portions of the program wherein the composite aileron design will be formulated and subcomponents fabricated and tested to verify design concepts and fabrication procedures. During Task III, Manufacturing Development, and Task IV, Ground Test and Flight Checkout,

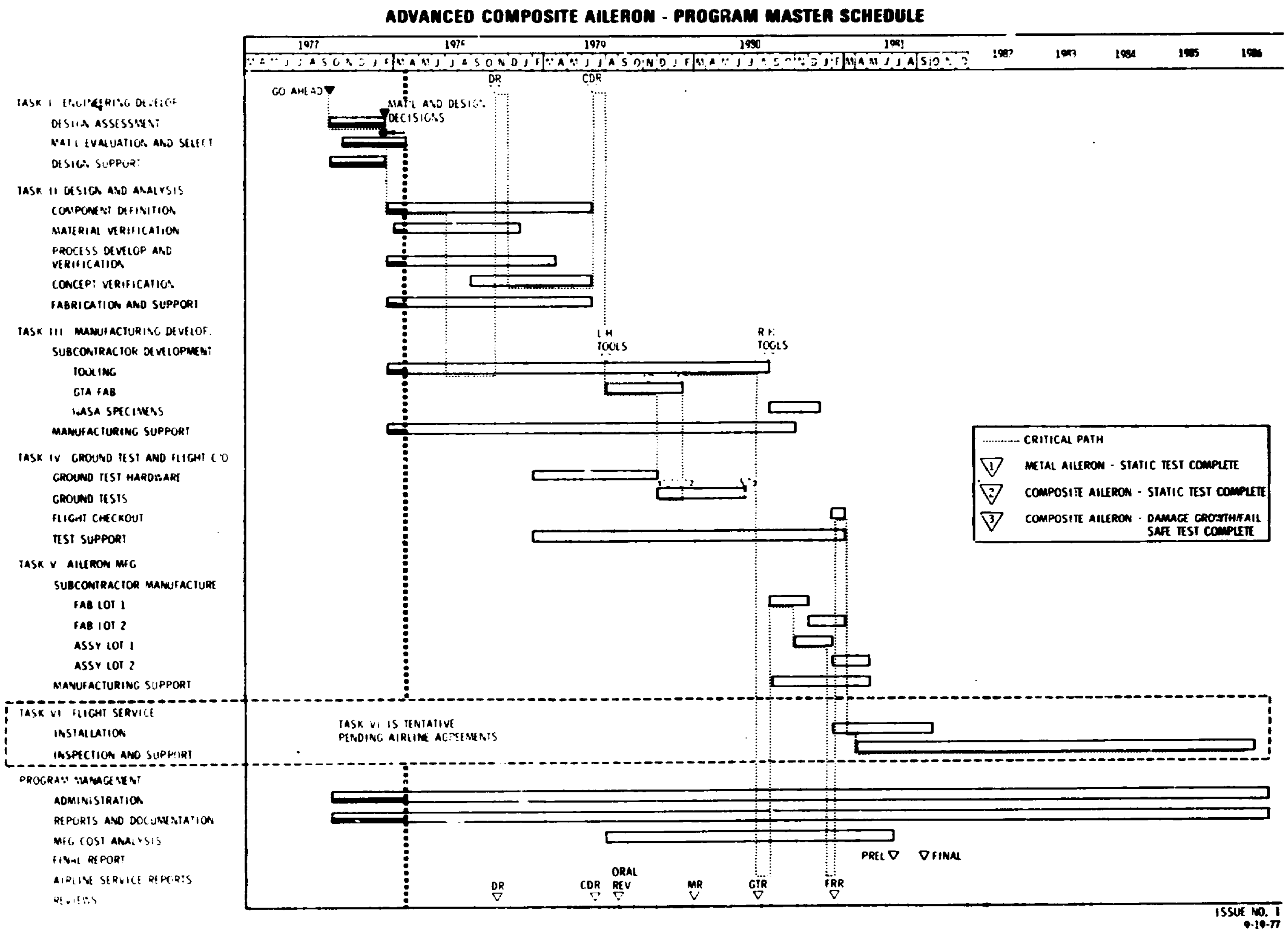

Figure 1-1. Advanced Composite Aileron - Program Master Schedule

production quality manufacturing tools will be constructed, and two full-scale ailerons will be fabricated and tested. A production run of ten (10) shipsets will be fabricated during Task V, Aileron Manufacture, to provide manufacturing and cost information. In Task VI, Flight Service, inspection and maintenance data will be gathered on the ten shipsets of ailerons to demonstrate that they can be economically operated in routine service. The work performed during this program is intended to provide the data required to progress toward a production commitment.

This report describes work accomplished during the second three-month period of the program. The two principal subtasks within Task I of the ACA program are design assessment and materials evaluation. Activities within these subtasks which have been completed during this reporting period are documented in Sections 2 and 3, respectively. Task II of the program has been initiated. Engineering and planning efforts during this reporting period are discussed in Sections 4 and 5.

SECTION 2

TASK I - ENGINEERING DEVELOPMENT, DESIGN ASSESSMENT

The objective of the design assessment subtask within Task I was to select a design concept for the ACA with the greatest potential for meeting the program objectives. The approach used for this activity was to define the design criteria, develop alternate designs, evaluate the alternatives against the cost and weight objectives, and select the best alternative. Design criteria and several of the alternate concepts for the subcomponents of the ACA were discussed in Quarterly Report Number 1 (Reference 1). The remainder of the subcomponent alternate concepts, the assembly evaluation, and the selected design for the ACA are presented in the following paragraphs.

2.1 ALTERNATE CONCEPTS

Alternate concepts were designed and evaluated for covers, front and rear spars, main and intermediate ribs, and rib backup fittings. Combinations of these subcomponents were then assembled and these assemblies evaluated to make the final concept selection. The design and evaluation of the covers, spars, and ribs was reported in Quarterly Technical Report No. 1 (Reference 1). During this reporting period the evaluation of the rib backup fittings, the main ribs with the backup fittings included, and the aileron assemblies was completed.

2.1.1 Rib Backup Fittings

Three designs for the rib backup fitting were evaluated; a graphite tape bathtub, a graphite fabric bathtub, and a dieforged aluminum bathtub. The evaluation matrix for the rib backup fitting is shown in Table 2-1. As a

TABLE 2-1. RIB BACKUP FITTING EVALUATION MATRIX

COMPONENT	BACK-UP FITTING		
CONCEPT		BATHTUB	
MATERIAL	ALUMINUM #3	GR — TAPE #1	GR — CLOTH #2
Weight (lb)	0.70	0.48	0.52
Cost Ratio	0.18	1.00	1.07
Tooling and Manufacturing Processes	Good	Poor	Poor
Inspectability	Good	Fair	Fair
Impact Resistance	Good	Good	Good
Environmental Sensitivity	Fair	Good	Good
Maintainability	Fair	Fair	Fair
Repairability	Not applicable (1)	Not applicable (1)	Not applicable (1)
Remarks	(1) Replace Fitting	(1) Replace Fitting	(1) Replace Fitting

consequence of its very low cost as compared to the composite designs, the dieforged aluminum fitting was selected for the assemblies. A drawing of this part is shown in Figure 2-1.

2.1.2 Main Ribs

The main rib designs and their evaluation were discussed in Quarterly Technical Report No. 1 (Reference 1). Three main ribs are included in the aileron assembly. The main ribs at IAS 57 and IAS 102 are connected to hinge/actuator fittings through the spar web. The main rib at IAS 107 is connected to an actuator fitting. Rib backup fittings are used to facilitate transmission of the concentrated loads from the rib web and caps. The rib backup fitting in the current metal aileron is a full-depth fitting designed to

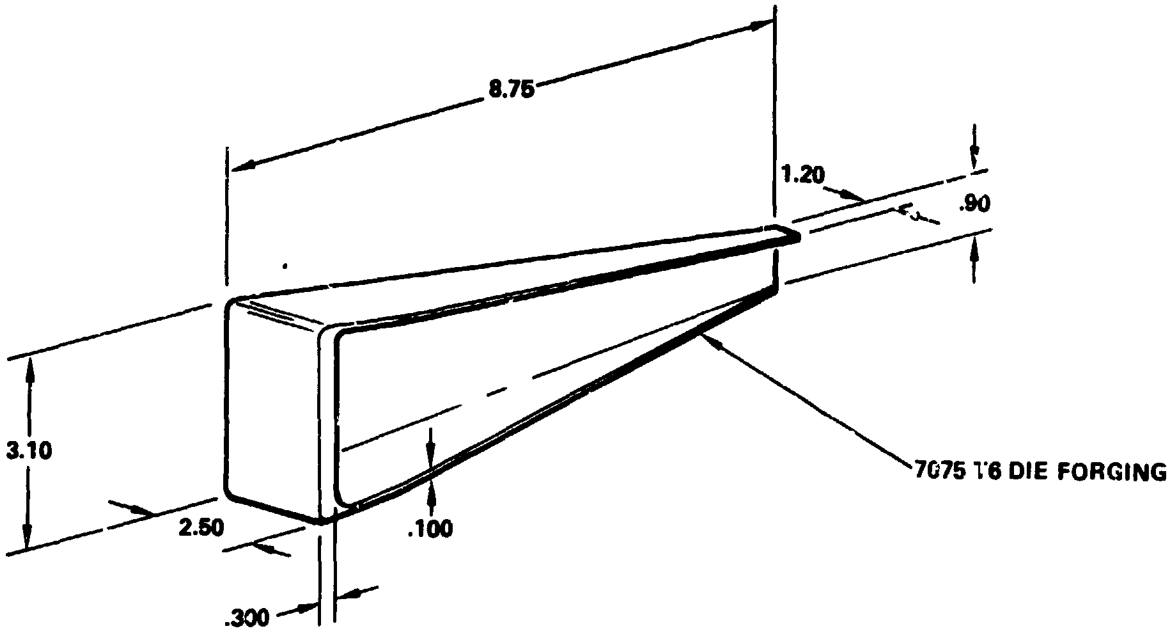

Figure 2-1. Aluminum Dieforged Hinge and Actuator Backup Fitting
(All dimensions shown in inches)

transmit the rib web shear as well as the rib cap loads. Two of these fittings are required per main rib. For the composite designs, the aluminum bathtub fitting was selected, since the composite rib web is flanged at the spar interface to transmit the web shear. Four bathtub fittings are required for the composite main ribs at IAS 57 and IAS 102, and three are used at IAS 107. A comparison of a typical aluminum main rib subassembly with the composite main rib designs is shown in Table 2-2. Concepts #1 and #2 were selected for evaluation in assemblies because of their low cost and weight compared to the other designs which were evaluated.

2.1.3 Aileron Assembly

The preliminary evaluation of the cover concepts led to the selection of two concepts for evaluation as ACA assemblies. They are graphite tape/ syntactic core with five intermediate ribs, and Kevlar honeycomb sandwich with no intermediate ribs. The two cover concepts were then combined with

TABLE 2-2. MAIN RIB EVALUATION MATRIX

CONCEPT	PLAIN WEB					STIFFENED
CONCEPT NO.		1	2	3	4	5
MATERIAL AND CONSTRUCTION	ALUMINUM	GRAPHITE TAPE (7.5 MILS/ PLY)	GRAPHITE CLOTH	GRAPHITE TAPE SYNTACTIC CORE (5 MILS/ PLY)	GRAPHITE TAPE KEVLAR 49 CLOTH CORE. (5 MILS/ PLY)	GRAPHITE TAPE (7.5 MILS/ PLY)
WEIGHT (LB)*	5.44	3.50	3.49	3.35	3.56	3.48
COST RATIO*	1.00	0.92	0.98	1.01	1.02	1.05

*Includes Rib Backup Fittings

preliminary selections for each of the subcomponents evaluated. The two resultant assemblies are shown in Figures 2-2 and 2-3. The evaluation of these assemblies, shown in Table 2-3, led to the selection of the multirib concept for the ACA.

2.1.4 Concept/Materials Interactive Study

Materials trade studies indicated advantages for both graphite fabric and graphite preplied tape for the various subcomponents of the ACA. Consequently, design iterations were required to determine the interaction between design concepts and material form and to determine the best combination of both. Subcomponent designs described in this report and the previous report (Reference 1) were used to develop aileron assemblies using: all-graphite preplied tape, assembly concept #3; all-graphite fabric, assembly concept #4; and the best combination of tape and fabric, assembly concept #5. The results of this study are summarized in Table 2-4.

AILERON CONCEPT NO. 1
(HONEYCOMB STIFFENED COVER)

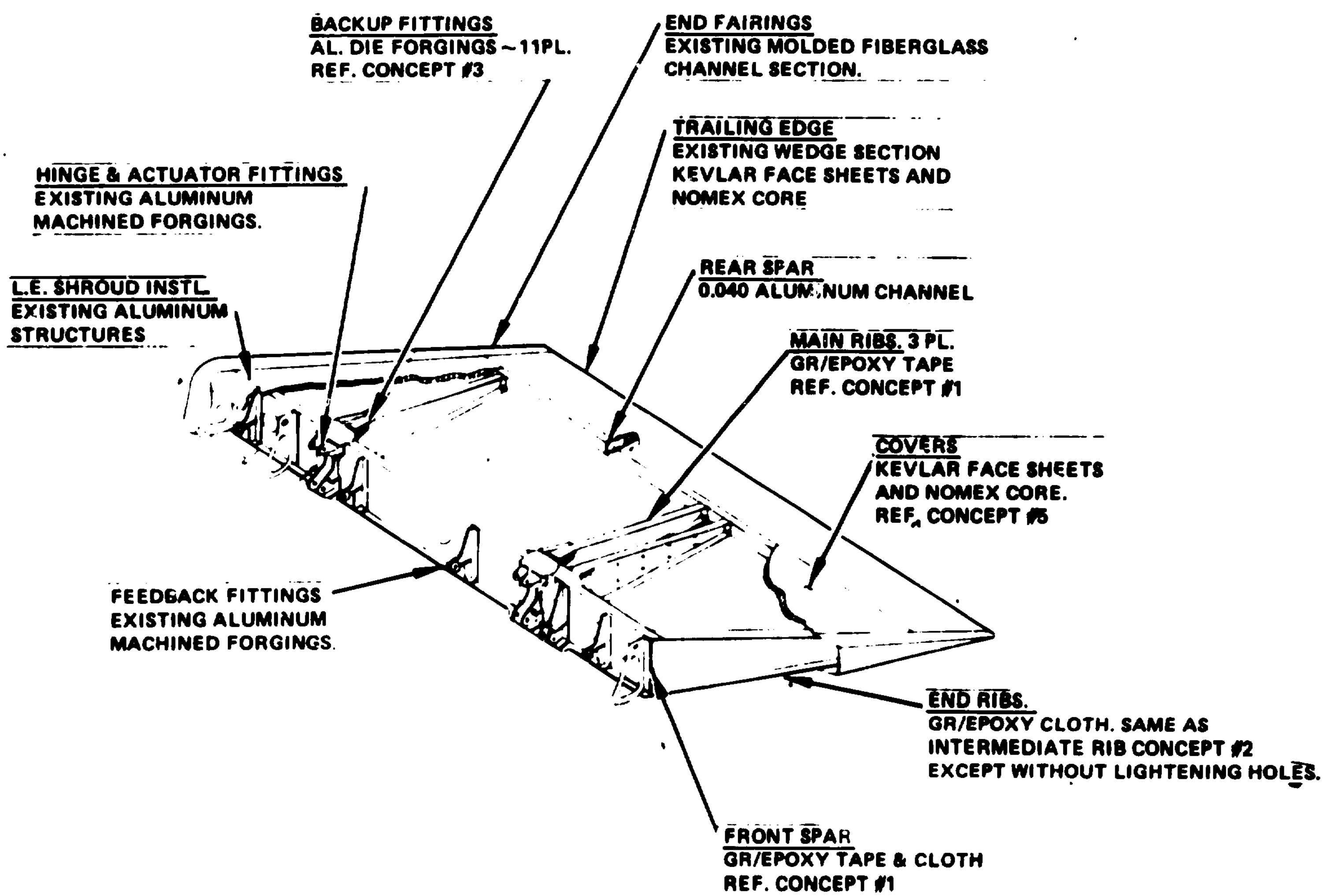

Figure 2-2. L-1011 Inboard Aileron Concept #1

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AILERON CONCEPT NO. 2
(MULTI - RIB WITH SYNTACTIC CORE COVER)

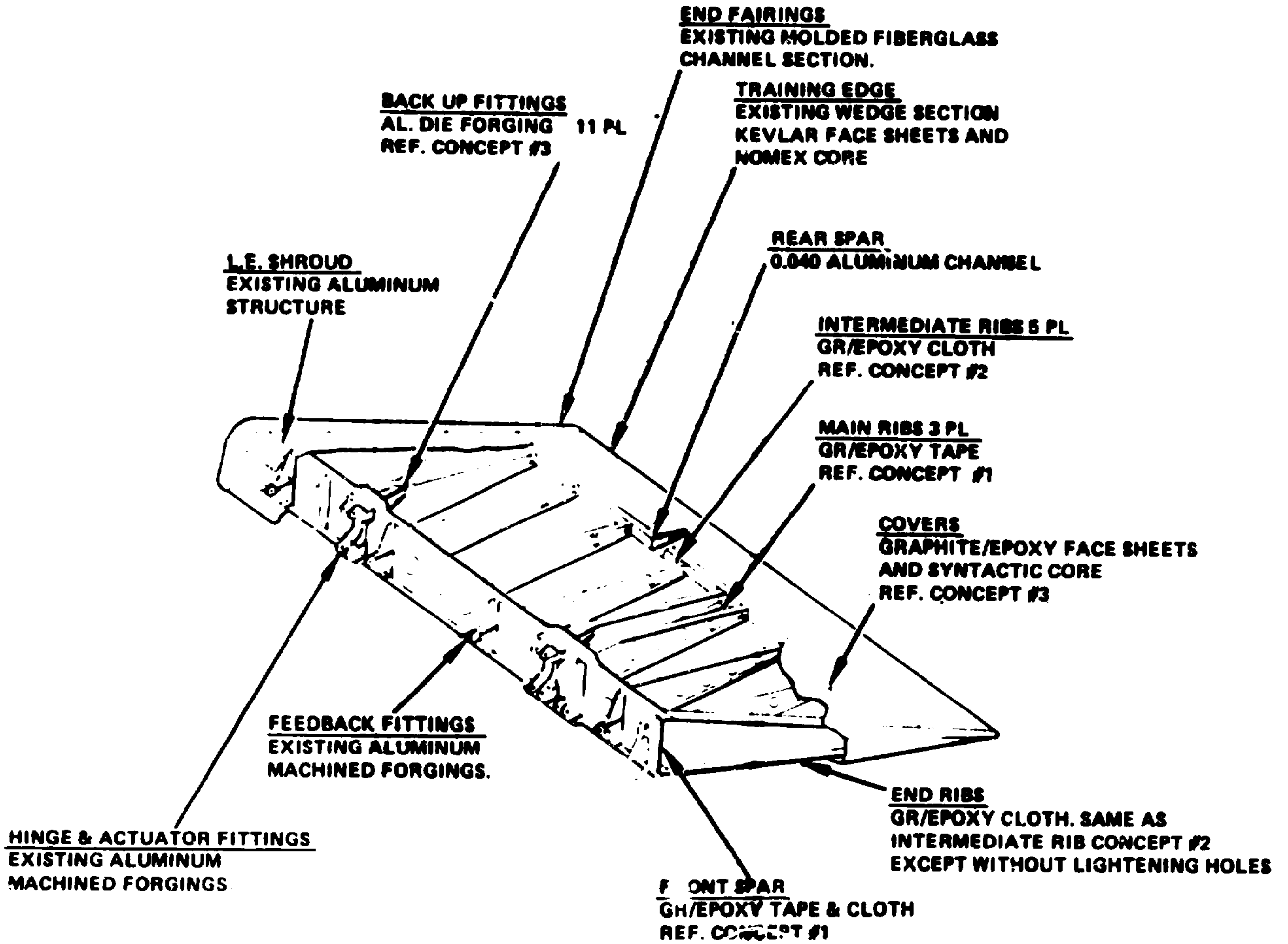

Figure 2-3. L-1011 Inboard Aileron Concept #2

TABLE 2-3. AILERON ASSEMBLY EVALUATION MATRIX

COMPONENT	INBOARD AILERON ASSEMBLY		
CONCEPT AND MATERIALS	MULTIRIB - ALUMINUM	SANDWICH - COMPOSITE #1	MULTIRIB - COMPOSITE #2
Cover	Sheet - AL	#5 Kevlar Face/Nomex Core	#3 Gr. Tape/Syntact. Core
Front Spar	I Section - AL	#1 Gr. Tape/Cloth	#1 Gr. Tape/Cloth
Rear Spar	I Section - AL	Aluminum Channel	Aluminum Channel
Main Ribs	Plain Web - AL	#1 Gr. Tape	#1 Gr. Tape
Intermediate Ribs	Truss - AL	--	#2 Gr. Cloth
End Ribs	Stiffened - AL	Gr. Cloth	Gr. Cloth
Back-Up Fittings	Bathtub - AL	#3 AL. Die Forgings	#3 AL. Die Forgings
No. of Subassemblies	27	6	14
No. of Fasteners	3112	1394	1634
Weight	140.4	119.5 ②	105.1 ②
Cost Ratio	1.00	0.90	0.94
Tooling and Manufacturing Processes	CURRENT DESIGN	Good	Fair
Inspectability		Fair	Good
Impact Resistance		Fair	Good
Environmental Sensitivity		Poor	Good
Maintainability		Good	Fair ①
Repairability		Good	Good

REMARKS: ① More fasteners required. ② Includes 5% growth.

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TABLE 2-4. CONCEPT/MATERIALS REFINEMENT

COMPONENT DESCRIPTION	ASSEMBLY CONCEPT NUMBER			
	#2	#3	#4	#5
Cover	Tape #3	Tape #3	Fabric #10	Tape #3
Front Spar	Tape & Fabric #1	Tape #4	Fabric #5	Tape #4
Intermediate and End Ribs	Fabric #2	Tape #6	Fabric #2	Fabric #2
Main Ribs	Tape #1	Tape #1	Fabric #2	Fabric #2
Rear Spar	Aluminum	Aluminum	Aluminum	Aluminum
Backup Fitting	Aluminum	Aluminum	Aluminum	Aluminum
Weight * (LB)	100.0	98.9	102.4	99.6
Cost Ratio to Aluminum	.94	-	-	.93

* Without Design Growth Allowance

2.2 SELECTED ACA DESIGN CONCEPT

A review of the assemblies shown in Table 2-4 showed that concept #5 with fabric ribs and 7.5 mil preplied graphite tape front spar and covers (with syntactic core) represented the most effective design. The selected concept is shown in Figure 2-4, and its weight statement is shown in Table 2-5.

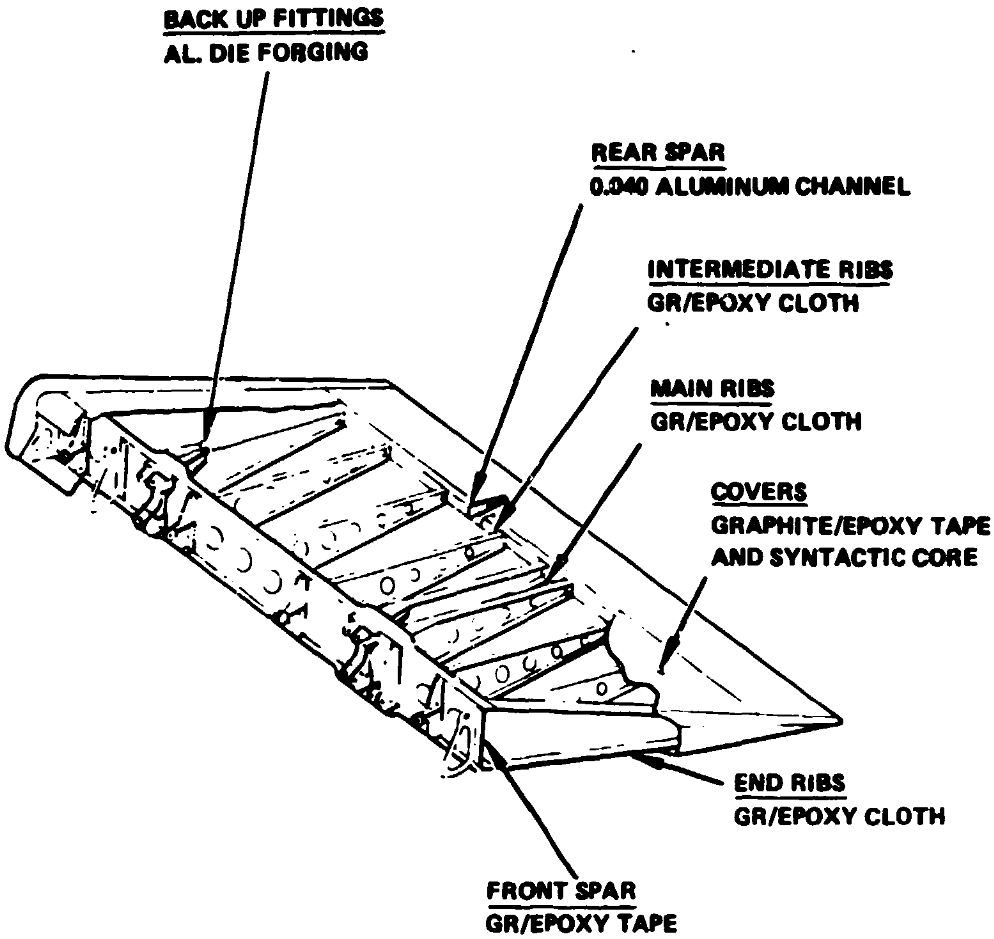

Figure 2-4. Selected ACA Concept and Materials

TABLE 2-5. COMPOSITE AILERON WEIGHT BREAKDOWN

COMPONENT	ALUMINUM BASELINE WT (LBS)	COMPOSITE CONCEPT #5 WT (LBS)
Surfaces ①	39.3	28.7
Ribs ②	39.3	(20.0)
IAS 57		3.9
102		3.9
107		3.0
INBD Closeout		1.6
OUTBD Closeout		1.6
Intermediate ⑤		6.0
Spars ②	15.9	(9.7)
Front		5.8
Rear		3.9
Fairing and Shroud ② ③	16.2	(16.9)
LE Shroud		10.5
INBD Fairing		2.9
OUTBD Fairing		3.5
T.E. Wedge Assy ④	12.6	6.0
Attach Hardware ⑤	4.2	2.7
Surface Protection	3.4	(6.1)
Lightning ⑥		2.7
Finish/Sealant		3.4
Existing FRT Spar Figs ①	9.5	9.5
Design Growth Allowance	-	5.0
Predicted Weight - Aileron	140.4	104.6
Weight Saving		35.8
% Weight Saving		25.5%

NOTES:
① No fasteners
② Incl: upper surface fasteners; lower surface platenuts
③ Identical to baseline except hi-loks instead of rivets for shroud to spar attachment
④ Incl: fasteners (bolts and washers)
⑤ Remaining assembly and installation hardware
⑥ Aluminum flame spray

SECTION 3

TASK I - ENGINEERING DEVELOPMENT, MATERIAL EVALUATION

The first part of material evaluation activities in Task I consisted of an initial qualitative screening of candidate prepregs, the results of which were reported in the First Quarterly Report (Reference 1). Three resin systems were selected for inclusion in the Task I quantitative screening tests: Narmco 5208, Fiberite 934, and Hexcel F-263. The qualitative screening study also identified three filamentary reinforcement types as having potential application to the ACA design. These were unidirectional graphite tape, graphite fabric, and Kevlar 49 fabric reinforcements. The quantitative screening consisted of structural screening tests performed at Lockheed and producibility screening tests performed at AVCO.

3.1 STRUCTURAL SCREENING TESTS

The quantitative screening test plan is shown in Table 3-1. This test plan was designed to determine the following critical factors for selection of the resin system:

- Retention of 180°F mechanical properties in high-humidity environments
- Retention of mechanical properties after impact damage
- Fabricability and mechanical properties as cocured skins for honeycomb sandwich construction
- Compatibility and mechanical properties as cocured skins for syntactic epoxy construction
- Resin/fiber interface bond strength with Kevlar 49.

A preliminary process development task was performed prior to specimen fabrication to develop acceptable procedures for test-panel fabrication.

TABLE 3-1. QUANTITATIVE SCREENING TESTS FOR COMBINATIONS OF RESINS AND REINFORCEMENTS

Type Of Test	(a) Temperature	Graphite (g) Tape			Graphite (h) Cloth			Graphite Tape/ Syntactic			Kevlar (i) Cloth			Hybrid		
		(e) A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Sandwich Beam Compression	RTD	(f) 3	3	3	-	-	-	-	-	-	(f) 3	3	3	(f) 3	3	3
Interlaminar Tension	RTD	(f) 3	3	3	-	-	-	(b) 3	3	3	(f) 3	3	3	(f) 3	3	3
Sandwich Beam (c) Compression After Impact	RTD	(f) 3	3	3	-	-	-	(b) (d) 3	3	3	(f) 3	3	3	(f) 3	3	3
Laminate Compression	355.4°K (180°F) Wet	3	3	3	-	-	-	(b) 3	3	3	-	-	-	-	-	-
Laminate Short-Beam Shear	RTD 219.3°K (-65°F) Dry 355.4°K (180°F) Wet	3 - 3	3 - 3	3 - 3	3 - 3	3 - 3	3 - 3	(b) 3 3 3	3 3 3	3 3 3	3 3 3	3 3 3	3 3 3	3 3 3	3 3 3	3 3 3
Laminate Flexure	RTD 255.4°K (180°F) Wet	3 3	3 3	3 3	3 3	3 3	3 3	(b) 3 3	3 3	3 3	3 3	3 3	3 3	3 3	3 3	3 3
Dynamic Mechanical Analysis	Dry Wet	3 3	3 3	3 3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

NOTES:

(a) Numbers in temperature column indicate test temperature in degrees Fahrenheit. Letters: W - wet (7 day immersion at 338.7°K (150°F), D - dry, and RT - room temperature.

(b) A syntactic material (Hysol ADX 819) is used for the core.

(c) After impact the sandwich is tested as a beam with the impacted face in compression.

(d) After impact the Graphite tape/syntactic sandwich is tested in edgewise compression with platen supports.

(e) The letters A, B, and C are the resins (5208, 934 & F263) selected from qualitative screening.

(f) Bonded with AF143 adhesive.

(g) Nominal 0.013 cm (5 mils)/cured ply tape, 3000 tow fibers at 35% nominal resin content by weight.

(h) 24 x 23 8 harness satin bi-directional fabric 0.033 cm (13 mils)/cured ply nominal, 3000 tow fibers, at 35% nominal resin content by weight.

(i) Style 285 Kevlar 49 fabric, 43% nominal resin content by weight, 0.025 CM (10 mils)/cured ply nominal.

These activities were summarized in Table 3-5 of the First Quarterly Report (Reference 1) and an updated summary of further process development activities since that report is given in Table 3-2. Significant items in the process development activity include:

- Fabrication of solid laminate graphite, Kevlar 49 and hybrid specimens - Acceptable laminates were fabricated using modified vendor cure cycles. The bleeder arrangement was designed to achieve minimum flow with the 35 percent resin content prepreg system.

- Fabrication of graphite/syntactic panels - The syntactic test panels were fabricated using the same cure cycles used for solid laminate specimens with each of the three resins.

- Fabrication of honeycomb panels - Panels were fabricated with graphite faces cocured to the Nomex cure, using two procedures: a single-stage cocuring cycle, and prebleeding of the skins prior to cocuring. Excessive resin flow occurred with the single-stage procedure and extensive skin porosity was found in all panels by photomicrographs. The prebled skins had less porosity and resin flow, but in several instances graphite interlaminar failures occurred in flatwire tensile tests. In view of these problems and the limited available time for further process development, a decision was made to fabricate all honeycomb test panels with pre-cured, secondarily bonded skins.

A summary of test panels used in the structural screening tests is given in Table 3-3, along with results of tests used to verify quality of the panels.

The structural screening tests have been completed, and test results are given in Table 3-4 for the solid laminate specimens, in Table 3-5 for the graphite/syntactic specimens, and in Table 3-6 for the honeycomb test panels. The dynamic flexure test results on the graphite tape laminate specimens are shown in Figure 3-1.

Table 3-7 gives the ranking of test results for the three candidate systems. Narmco 5208 and Fiberite 934 have generally superior mechanical properties to Hexcel F-263. The 180°F wet flexure, short-beam shear, and compression values on the graphite tape laminates show the Hexcel F-263 system to be more affected by this environment than the other systems. The 180°F wet data on the graphite fabric laminates also show the Hexcel system with lower

TABLE 3-2. PROCESS DEVELOPMENT FOR STRUCTURAL SCREENING - SYNTACTIC AND HONEYCOMB PANELS ⚠1

MATERIAL DESCRIPTION			EVALUATION RESULTS						
RESIN	FIBER REINFORCEMENT	LAMINATE OR PANEL DESCRIPTION	RESIN CONTENT, % BY WT.	DENSITY g/cc.	NDI	PHOTO-MICRO-GRAPHS	FLATWISE TENSILE (psi)	INTERLAMINAR TENSILE (psi) ⚠2	REMARKS
Fiberite 934	T300 graphite unidirectional tape	14" x 12" (45, 0, 135, 0, syntactic epoxy 0.040", 0, 135, 0, 45) t = 0.065" with peel ply	-	1.38	No voids	No voids in skins; 50% crushed microspheres	-	1675-100G 1425-95G, 5A 1590-95G, 5A Avg. = 1563	Used Narmco laminate cure cycle as Narmco syntactic panel had best NDI results and lowest no. of crushed microspheres in previous trial. Quality proved comparable to previous trials.
Hexcel F-263	T300 graphite unidirectional tape	14" x 12" (45, 0, syntactic epoxy 0.040", 0, 135, 0, 45) t = 0.067" with peel ply	-	1.33	No voids	No voids in skins; 50% crushed microspheres	-	1550-95G, 5A; 1500-95G, 5A; 1650-95G, 5A Avg. = 1567	Same remarks as above
Fiberite 934	T300 graphite unidirectional tape (skins prestaged prior to cocuring)	14" x 12" with 6 ply faces (0, 45_2, 90, 135_2) 1/8-4.0 Nomex core, 5/8" t	Top 30.3 Bottom 28.0	Top 1.58 Bottom 1.59	Extensive voids	No voids top skin; voids in bottom skin est. 0.5%	478 465 470 Avg. = 471 (100% core failure)	-	No interlaminar failures as with other two prestaged panels, and higher resin content skins. Three prestaged panels all had comparable void contents as single stage cured panels, but less resin flow based on X-ray
Hexcel F-263	T300 graphite unidirectional tape (Skins prestaged prior to cocuring)	14" x 12" with 6 ply faces (0, 45_2, 90, 135_2) 1/8-4.0 Nomex Core, 5/8" t	Top 26.8 Bottom 21.8	Top 1.58 Bottom 1.54	Extensive voids	Voids in top skin est. 0.6% voids in bottom skin est. 1.1%	279 389* 295	-	*Specimens 1 and 3 were 100% graphite interlaminar failure in bottom skin; specimen 2 had 50% core failure, 50% graphite bottom skin interlaminar failure. Low resin content of bottom skin probable factor.
Narmco 5208	T300 graphite unidirectional tape (Skins prestaged prior to cocuring)	14" x 12" with 6 ply faces (0, 45_2, 90, 135_2) 1/8-4.0 Nomex core, 5/8" = t	Top 29.5 Bottom 23.5	Top 1.573 Bottom 1.56	Extensive voids	Voids in top skin est 0.53%; void in bottom skin est. 0.55%	355 338* 391		*Specimen 1, 30% core, 70% top skin delam.; #2 was 50% core, 50% bottom skin delam; #3 was 50% core; 50% top skin delam. Resin content less apparent factor here.

⚠1 This Table covers process development panels fabricated after preparation of First Quarterly Technical Report, and supplements Table 3-5 of that report.

⚠2 Interlaminar tensile failure modes: C = graphite interlaminar failure,

A = graphite/syntactic interface failure

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TABLE 3-3. STRUCTURAL SCREENING TEST PANELS

PANEL TYPE	RESIN	REINFORCEMENT	DESCRIPTION	RESIN CONTENT % BY V	DENSITY /cc.	NDI	PHOTOMICROGRAPHS	THICKNESS PER PLY (mils) △	FLATWISE TENSILE (psi)	INTERLAMINAR TENSILE (psi) △
Solid laminate	Narmco 5208	T300 graphite unidirectional tape	14" x 12" x 16 ply (0, 45, 0, 135, 0, 45, 0, 135)s	26.2	1.60	No voids	Very few, isolated small voids	5.0	-	-
		T300 graphite fabric 24 x 23 8 HS	14" x 12" x 8 ply (0, 45, 0, 135)s	25.6	1.58	No voids	No voids	13.4	-	-
		Kevlar 49 fabric Style 285	14" x 12" x 8 ply (45, 0, 135, 45)s	34.4	1.33	No voids	Scattered random, small voids	8.75	-	-
		T300 graphite tape/Kevlar 49 fabric Style 285 hybrid	14" x 12" (0_K, 45_{2G}, 135_{2G}, 0_K)s t = 0.077" with peel ply	32.65	1.505	No voids	No voids	-	-	-
	Fiberite 934	T300 graphite unidirectional tape	14" x 12" x 16 ply (0, 45, 0, 135, 0, 45, 0, 135)s	26.7	1.59	No voids	No voids	5.1	-	-
		T300 graphite fabric -24 x 23 8HS	14" x 12" x 8 ply (0, 45, 0, 135)s	31.9	1.57	No voids	No voids	13.5	-	-
		Kevlar 49 Fabric Style 285	14" x 12" x 8 ply (45, 0, 135, 45)s	41.0	1.39	No voids	No voids	8.75	-	-
		T300 graphite tape/Kevlar 49 fabric Style 285 hybrid	14" x 12" (0_K, 45_{2G}, 135_{2G}, 0_K)s t = 0.072"	31.0	1.51	No voids	No voids	-	-	-
	Hexcel F-263	T300 graphite unidirectional tape	14" x 12" x 16 ply (0, 45, 0, 135, 0, 45, 0, 135)s	28.7	1.57	No voids	No voids	5.2	-	-
		T300 graphite fabric 24 x 23 8 HS	14" x 12" x 8 ply (0, 45, 0, 135)s	21.3	1.59	No voids	No voids	13.0	-	-
		Kevlar 49 fabric Style 285	14" x 12" x 8 ply (45, 0, 135, 45)s	35.3	1.37	No voids	No voids	8.25	-	-
		T300 graphite tape/Kevlar 49 fabric Style 285 hybrid	14" x 12" (0_K, 45_{2G}, 135_{2G}, 0_K)s t = 0.072" with peel ply	31.3	1.49	No voids	No voids	-	-	-
Syntactic Panel	Narmco 5208	T300 graphite unidirectional tape/syntactic epoxy	30" x 10.5" (45, 0, 135, 0, syntactic, 0, 135, 0, 45) t = 0.071" with peel ply	-	1.2	No voids	Slight voids one area; est. 25% crushed microspheres	-	-	2000 (60G, 40S) 1800 (100G) 1550 (100G) Avg. - 1783
	Fiberite 934	T300 graphite unidirectional tape/syntactic epoxy	30" x 10.5" (45, 0, 135, 0, syntactic, 0, 135, 0, 45) t = 0.076"	-	1.31	No voids	No voids; est. 50% crushed micropheres	-	-	2680 (100G) 2530 (40G, 60A) 2800 (100G) Avg. = 2670
	Hexcel F-263	T300 graphite unidirectional tape/syntactic epoxy	30" x 10.5" (45, 0, 135, 0, syntactic, 0, 135, 0, 45) t = 0.089"	-	1.08	No voids	No voids; very few crushed microspheres	-	-	2460 (90S, 10G) 2440 (97B, 3G) 2630 (97B, 3G) Avg. - 2507

TABLE 3-3. STRUCTURAL SCREENING TEST PANELS (Continued)

PANEL TYPE	RESIN	REINFORCEMENT	DESCRIPTION	RESIN CONTENT % BY WT	DENSITY g/cc.	NDI	PHOTOMICROGRAPHS	THICKNESS PER PLY (mils) ⚠1	FLATWISE TENSILE (psi)	INTERLAMINAR TENSILE (psi) ⚠2
Honeycomb Sandwich	Narmco 5208	T300 graphite unidirectional tape skins	30" x 30"; 6 ply skins (0, 45_2, 90, 135); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-		392	-
		Kevlar 49 fabric style 285 skins	30" x 20"; 4 ply skins (45, 0, 135, 45); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	375	-
		T300 graphite tape/Kevlar 49 fabric hybrid skins	30" x 20"; skins (0_k, 45_{2G}, 135_{2G}, 0_k); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	361	-
	Fiberite 934	T300 graphite unidirectional tape skins	30" x 30"; 6 ply skins (0, 45_2, 90, 135_2); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	372	-
		Kevlar 49 fabric style 285 skins	30" x 20"; 4 ply skins (45, 0, 135, 45); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	349	-
		T300 graphite tape/ Kevlar 49 fabric hybrid skins	30" x 20"; skins (0_k, 45_{2G}, 135_{2G}, 0_k); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	370	-
	Hexcel F-263	T300 graphite unidirectional tape skins	30" x 30"; 6 ply skins (0, 45_2, 90, 135_2); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	372	-
		Kevlar 49 fabric style 285 skins	30" x 20"; 4 ply skins (45, 0, 135, 45); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	369	-
		T300 graphite tape/Kevlar 49 fabric hybrid skins	30" x 20"; skins (0_k, 45_{2G}, 135_{2G}, 0_k); 1/8 - 4.0 Nomex core, 5/8-in. thick	-	-	No voids	-	-	365	-

⚠1 Thickness per ply calculated after subtraction for peel ply from measurement. 6 mils assumed for 2 peel ply surfaces

⚠2 Failure modes for interlaminar tensiles given in percentages: G = graphite interlaminar; S = syntactic failure; A = graphite/syntactic interface; B = loading block failure

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TABLE 3-4. MATERIAL SCREENING - SOLID LAMINATE TEST RESULTS

TEST		FLEXURE				SHORT-BEAM SHEAR			LAMINATE COMPRESSION		INTERLAMINAR TENSILE		
TEMPERATURE-CONDITION		RTD		180W		RTD	180W	-65D	180W		RTD		
FORM	RESIN	STRESS KSI	MODULUS MSI	STRESS KSI	MODULUS MSI	STRESS PSI	STRESS PSI	STRESS PSI	STRESS KSI	MODULUS MSI	STRESS PSI	RESIN CONT % / % FIBER VOLUME	LAMINATE DENSITY g/cc
Graphite Tape	5208	176.3	14.6	168.5	21.0	7425	7302	-	103.8	-	1733	26.20 / 67.5	1.60
$(0/45/0/135)_{2S}$	934	187.2	13.9	162.1	19.9	11026	9103	-	102.3	-	2770	26.7 / 66.5	1.59
	F263	159.4	12.3	136.2	12.9	7134	4991	-	75.0	-	1393	28.7 / 63.8	1.57
Graphite Fabric	5208	99.3	8.46	106.4	9.6	8916	8184	-	-	-	-	25.6 / 67.0	1.58
$(0/45/0/135)_s$	936	99.8	7.99	79.8	7.8	10370	8410	-	-	-	-	31.9 / 61.0	1.57
	F263	100.2	8.81	72.3	8.6	10086	6869	-	-	-	-	26.3 / 67.0	1.59
Kevlar-49 Fabric	5208	42.3	2.85	30.8	2.2	3843	2527	3750	-	-	1693	34.4 / 60.2	1.33
$(45/0/135/45)_s$	934	32.0	1.78	31.0	1.42	3762	2790	2978	-	-	1338	41.0 / 56.6	1.39
	F263	34.6	1.85	30.8	1.73	3117	2742	3199	-	-	1443	35.3 / 61.1	1.37
GR. Tape/Kev Fabric	5208	58.9	5.21	54.3	4.2	3632	2702	2930	-	-	1793	32.65 / -	1.505
Hybrid	934	63.1	3.54	56.3	2.3	3458	2970	3749	-	-	1120	31.0 / -	1.51
$(0_k/\pm45_{2G}/0_k)_s$	F263	54.4	3.38	54.9	3.2	3753	3407	3410	-	-	1160	31.3 / -	1.49

NOTE: All values are average of three tests.

RTD = Room temperature tests unconditioned

-65D = 65°F tests unconditioned

180W = 180°F tests after 7 days immersion in distilled water @ 150°F

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TABLE 3-5. MATERIAL SCREENING OF GRAPHITE/SYNTACTIC - SUMMARY OF TEST RESULTS

TYPE OF TEST			5208	934	F263
Compression	RTD	KSI	73.8	72.3	55.5
	THICK	IN	.071	.072	.084
Compression after impact	RTD	KSI Δ5	58.7	56.0	54.6
		Δ6	41.3	45.0	39.4
Flexure Δ1	RTD STR	KSI	122.5	143.9	114.9
	MOD	MSI	7.4	8.2	7.1
	THICK	IN	.077	.070	.082
	180W STR	KSI	119.7	120.8	104.[illegible]
	MOD	MSI	10.8	10.6	10.3
	THICK	IN	.073	.063	.082
Short-Beam Shear	RTD	PSI	2789 Δ2	3137 Δ2	1614 Δ3
	THICK	IN	.069	.072	.081
	-65D	PSI	3542 Δ3	2690 Δ2	1520 Δ3
	THICK	IN	.068	.072	.081
	180W	PSI	2143 Δ2	2259 Δ3	1309 Δ3
	THICK	IN	.069	.073	.083
Interlam. Tension	RTD	PSI Δ4	2212	2190	1580 Δ2
Density		g/cc	1.20	1.31	1.08

NOTE:
- Average of three tests
- Nominal Thickness = .020 each face + .040 core = .080 total
- Δ1 Span-to-thickness ratio = 32
- Δ2 Coef. of variation > 10%
- Δ3 Coef. of variation > 20%
- Δ4 Most failure modes graphite to syntactic.
- Δ5 Least Damage
- Δ6 Most Damage
- Layup: (45/0/135/0/SYN)s
- RTD = Room temperature tests unconditioned
- 180W = 180°F tests after 7 days immersion in distilled water at 150°F

TABLE 3-6. MATERIAL SCREENING OF HONEYCOMB SANDWICH TEST SPECIMENS

PANEL CONSTRUCTION	RESIN	SANDWICH BEAM COMPRESSION COMPRESSIVE STRENGTH (ksi)	
		CONTROL	AFTER IMPACT **
Graphite Tape Skins (0, 45_2, 90, 135_2); 1/8 - 4.0 PCF Nomex core, 5/8 in. thick.	Narmco 5208	39.3	38.2
	Fiberite 934	50.6	37.4
	Hexcel F-263	46.6	33.3
Kevlar-49 Fabric Skins (45, 0, 135, 45); 1/8 - 4.0 PCF Nomex core, 5/8 in. thick.	Narmco 5208	20.5	18.1
	Fiberite 934	19.2	16.8
	Hexcel F-263	19.9	16.9
Graphite Tape/Kevlar-49 Hybrid Skins (0_k, 45_{2G}, 135_{2G}, 0_k); 1/8 - 4.0 PCF Nomex core, 5/8 in. thick.	Narmco 5208	26.4	26.8
	Fiberite 934	25.8	25.8
	Hexcel F-263	26.4	24.3

**Impacted at 2. ft lb with 1.0 in. dia sphere

TABLE 3-7. RANKING OF QUANTITATIVE SCREENING TEST RESULTS
(Scale of 1 to 3, 1 Being Best)

TYPE OF TEST			GRAPHITE TAPE			GRAPHITE FABRIC			KEVLAR FABRIC			HYBRID GRAPHITE/KEV.			GR TAPE/ SYNTACTIC		
			5208	934	F263	5208	934	F263	5208	934	F263	5208	934	F263	5208	934	F263
LAM. COMPR.		180W	1	2	3	–	–	–	–	–	–	–	–	–	–	–	–
LAMINATE FLEXURE	RTD	STR	2	1	3	3	2	1	1	3	2	2	1	3	2	1	3
		MOD	1	2	3	2	3	1	1	3	2	1	2	3	2	1	3
	180W	STR	1	2	3	1	2	3	2	1	2	3	1	2	2	1	3
		MOD	1	2	3	1	2	3	1	3	2	1	3	2	1	2	3
	AVCO RTD	STR	1	2	3	–	–	–	–	–	–	–	–	–	–	–	–
LAMINATE SHORT-BEAM SHEAR	STR	RTD	2	1	3	3	1	2	1	3	2	2	3	1	2	1	3
		–65D	–	–	–	–	–	–	1	3	2	1	2	3	1	2	3
		180W	2	1	3	2	1	3	3	1	2	3	2	1	2	1	3
	AVCO	RTD	1	2	3	–	–	–	–	–	–	–	–	–	–	–	–
INTLAM. TENS		RTD	2	1	3	–	–	–	1	3	2	1	3	2	1	2	3
DYNAMIC MECHANIC. ANALYSIS		DRY	1	2	3	–	–	–	–	–	–	–	–	–	–	–	–
		WET	1	2	3	–	–	–	–	–	–	–	–	–	–	–	–
AVERAGE RANK			1.3	1.7	3	2	1.8	2.2	1.4	2.5	2	1.8	2.1	2.1	1.6	1.4	3

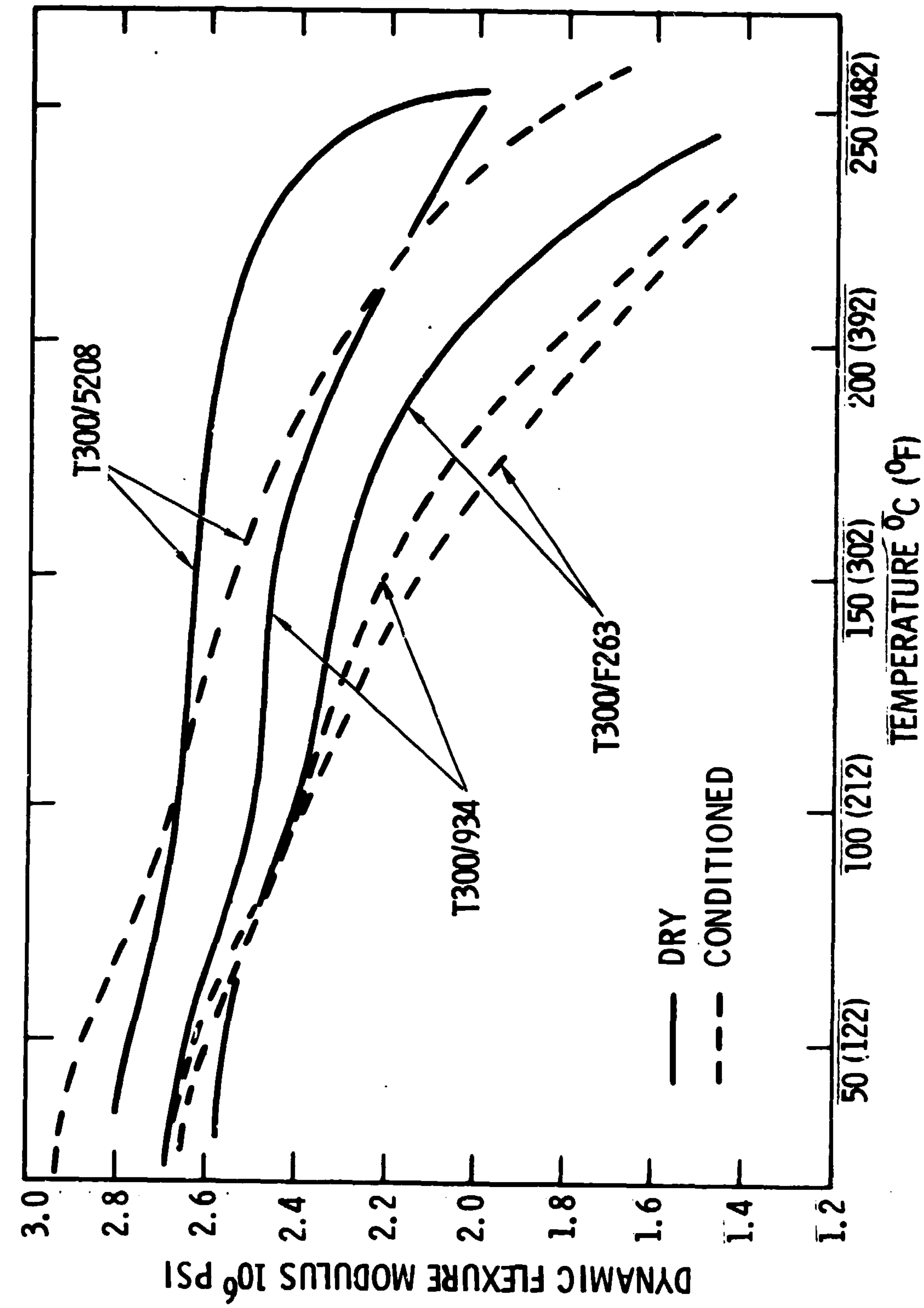

Figure 3-1. Dynamic Flexure Test Results

values. Narmco 5208 and Fiberite 934 are more closely comparable, but on balance Narmco system holds an edge in hot, wet properties and in general mechanical properties. The Kevlar 49 data provides less distinction between the three systems, but the elimination of Kevlar 49 from the design concepts made this data of less significance in the resin selection.

The dynamic flexure curves provide the clearest ranking of the three resins, with Narmco 5208 significantly superior in the dry condition and after moisture exposure. The relative superiority of Narmco 5208 in this property increases with increased temperature and moisture exposure.

The graphite/syntactic test data also showed Narmco 5208 and Fiberite 934 having superior mechanical properties over Hexcel F-263, particularly in short-beam shear. Fiberite 934 showed some higher values than Narmco 5208 in flexure and short-beam shear. In summary, the syntactic panels must be considered as not clearly differentiating between the three candidate resins, but the data does demonstrate compatibility of the syntactic system with the three candidate resins.

The honeycomb sandwich test panels were impacted at a two foot pound energy level using a steel rod and residual sandwich beam compression properties were determined. The results showed a greater proportional drop occurred with the graphite faced panels than with the Kevlar 49 or hybrid faced panels. Beam compression values after impact on the graphite panels were comparable for the three resins, and the results did not indicate any significant differences in impact resistance of the three candidate resins.

3.2 PRODUCIBILITY SCREENING TESTS

The producibility aspects of the three candidate resin systems were evaluated by Avco. Flat plates, sections of the rib configuration, and sandwich plates were fabricated. During fabrication the tack, backing paper adhesion, bleed characteristics, drilling and sawing characteristics, and drapability were evaluated. The results of this evaluation, shown in Table 3-8, do not indicate a clear-cut producibility superiority of one system over the other two.

TABLE 3-8. MATERIALS PRODUCIBILITY EVALUATION

NO.	Resin Type	Material	Construction	Size & Type	General Qualitative Analysis: Tack	Backing Paper ADH.	Bleed	Drill	Saw	Drape
P1 P2 P3	5208 934 263	Gr Tape	16 Ply $(45^o, 90^o, 135^o, 0^o)_{2s}$	60.96 cm (24 in) x 91.44 cm (36 in) Plate SOLID GR	G F G	G F G	P P P	F F F	G G G	- F F
P4	5208	Gr Tape Syntactic	4 Ply, 1 Ply, 4 Ply $(45^o, 90^o, 135^o, 0^o)_s$	GR, SYN, GR	G	G	F	F	G	-
R1	5208	GR Tape	8 Ply $(45^o, 90^o, 135^o, 0^o)_s$	30.48 cm (12 in) Rib Section Solid GR	-	G	-	-	-	F
R2 R3 R4	5208 934 263	24 x 23 GR Fabric 8HS	3 Ply $(45^o, 0^o, 135^o)$	30.48 cm (12 in) Rib Section Solid GR	F F F	- - -	- - -	- - -	- - -	G G G
S1 S2 S3	5208 934 263	K49 Nomex	Nomex Sand 4 Ply Face SH $(45^o, 0^o, 135^o, 45^o)_s$	60.96 cm (24 in) x 91.44 cm (36 in) Plate	P F P	P G P	- - -	- - -	- - -	F G P

LEGEND:
- C - Complete
- G - Good
- F - Fiar
- P - Poor
- X - Required
- \- - Not Required

Coupons for physical and mechanical property tests were machined from each of the parts described in Table 3-8. Data from fiber-volume measurements, short-beam shear, flexure, and flatwise tensile tests is presented in Table 3-9. In general, this data indicated that the 5208 system had the highest mechanical properties.

In evaluation of qualitative data, no one material was significantly better than the others. However, the following observations were;

- Fabric layup is easier than tape layup.
- All specimens were preplied prior to layup and drapability is better with fabric than tape.
- 48-inch fabric uses less labor to cut the composite than 12-inch tape.
- During layup, errors are more easily correctable with fabric than tape.
- Fabric materials with same resin content exhibit handling properties of tape materials of less resin content; this is a result of the method of resin impregnation. This condition is more pronounced with older materials.
- The surface finish on tape is better than with fabric.
- Syntactic sandwich panels are much easier to layup than honeycomb sandwich panels.
- The Kevlar panels are more difficult to cut and machine than graphite.
- The 285 Kevlar weave has good drapability on double-curved surfaces. The corners on the sandwich panels can be formed without slitting and lapping the corners.

TABLE 3-9. PRODUCIBILITY EVALUATION - SPECIMEN TEST RESULTS

Candidate No.	Material	Fiber Volume (1)		Short Beam Shear		Flexure (2)	
		Avg. %	Coef. Variation %	Avg. PSI	Coef. Variation %	Avg. PSI	Coef. Variation %
P1	5208 Tape (NARMCO)	68.40	2.0	8754	.105	88415	3.1
P2	934 Tape (FIBERITE)	69.17	.9	7499	,106	87551	5.7
P3	263 Tape (HEXCEL)	62.33	1.9	7025	.054	79453	6.1
P4	5208 Tape & ADX-819 Syn. (Hysol)	54.17	1.8	4410	.041	65140	3.4
R1	5208 Tape	73.12	3.6				
R2	5208 Fabric	66.67	2.2				
R3	934 Fabric	70.00	2.4				
R4	263 Fabric	69.17	2.4				
		Flatwise Tensile (3)					
		Avg. PSI	Coef. Variation				
S1	5208 - K49 - NOMEX	374.4	17.5				
S2	934 - K49 - NOMEX	370.8	7.5				
S3	263 - K49 - NOMEX	356.0	9.7				

(1) This number imcludes the weight of the microballoons within the syntactic epoxy core.
(2) Tension failure in tension fibers all specimens.
(3) Approximately 50% each core and skin failure, no bond line failures.

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In summary, the evaluation to date of the materials tested indicates that the fabric material with the Narmco 5208 resin is superior from a manufacturing producibility standpoint for the L-1011 advanced composite aileron.

As part of the producibility screening tests, Avco has made a preliminary evaluation of tooling techniques for the channel section ribs to be used for the aileron assembly. Graphite fabric ribs were made using both male and female tooling. Conventional bagging approaches and formed rubber bags (see Figures 3-2 and 3-3) were used on both tools. In addition, several ribs were made in a female tool using a formed rubber block in conjunction with a conventional vacuum bag.

Parts made in a female tool using a conventional vacuum bag or a formed rubber bag showed evidence of bridging and porosity in the radii of the rib. Parts made in the male tool showed no evidence of bridging in the radii; however, the parts did have a large dimensional variance. The dimensional problems using a male tool appear to be correctable to a large extent by tool development; however, the accumulation of tolerances to the outside mold lines for the ribs and spar could be a problem. Ribs fabricated using the female tool in conjunction with a rubber block and conventional bagging showed no evidence of bridging or porosity in the radii.

A preliminary evaluation of the tooling techniques investigated indicates that the female tool using a rubber block and conventional bag is the best method for fabricating the ribs and spar of the aileron. Additional process development activities will be conducted during Task II to firmly establish the fabrication approach.

3.3 SELECTED MATERIALS

In addition to the data from the structural screening tests, other factors entered into the selection of the resin system. These included the results of the Producibility Screening tests performed at Avco. Additional factors were available data base and processing history at Lockheed; and availability of the system in preplied tape form, which proved to be an essential factor in reducing production costs.

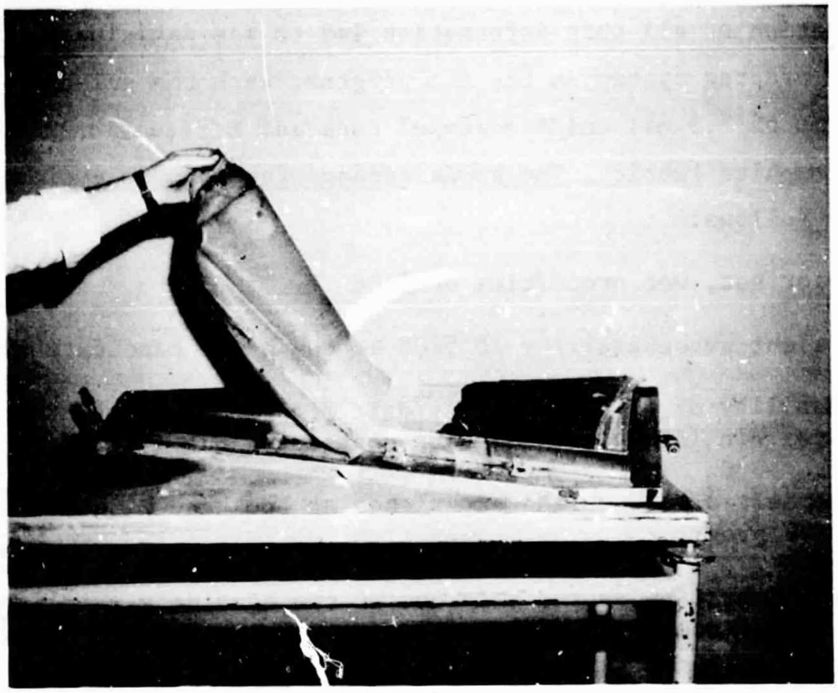

Figure 3-2. Male Tool Rubber Bag

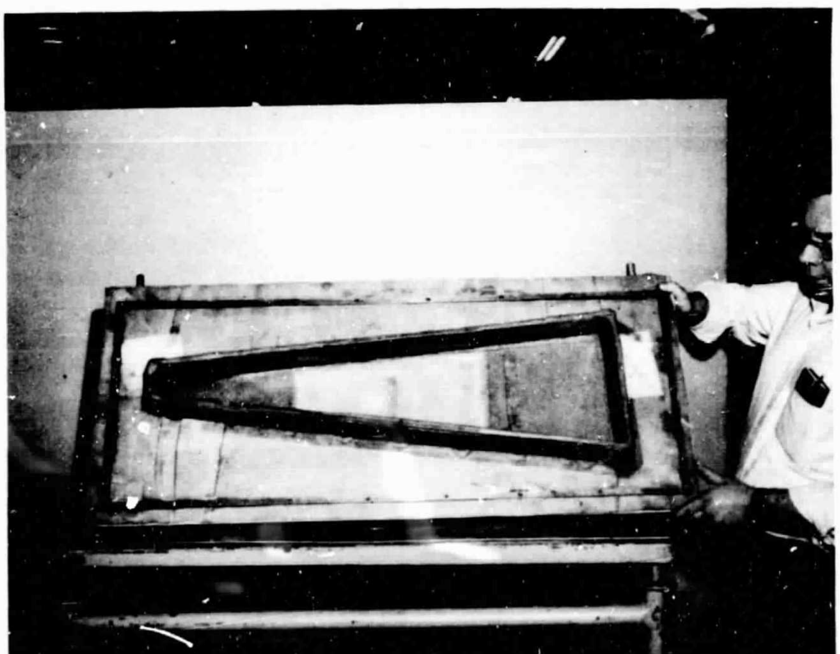

Figure 3-3. Female Tool Rubber Bag

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Consideration of all this information led to the decision to use Narmco's 5208 prepreg system in the ACA program, with the selected reinforcement forms of 7.5 mil unidirectional tape and bidirectional 13 mil, satin weave graphite fabric. The basic reasons for this selection are summarized as follows:

- Superior hot, wet properties of 5208
- Equivalent processability of 5208 to the other candidate systems
- Availability of 5208 allowables data from the Advanced Composite Vertical Fin (ACVF) Program NASA Contract NAS1-14000.
- Development of processing experience at Lockheed with 5208 from the ACVF program
- Narmco's position as the only one of the candidate suppliers to make a firm commitment for development of preplying capability.

SECTION 4

TASK II - DESIGN AND ANALYSIS, COMPONENT DEFINITION

Component definition, which is the design and analysis of the selected ACA concept, has been initiated during the reporting period. Activities within component definition are reported under the headings detail design, structural analysis, and material and producibility analysis.

4.1 DETAIL DESIGN

The basic design and interface requirements drawing has been completed. This drawing (Figure 4-1) defines existing parts which will be used unchanged, interchangeability requirements, electrical bonding and grounding, drainage, smoothness and gaps, and identifies new detail parts, assemblies, and installations; it is for design control only, and authorizes no fabrication or tooling.

Detail design activity for the covers has been initiated. Alternate approaches to the intersection of the rib doublers and spar doublers are curre being investigated. Results of these studies will be included in the next technical report.

4.2 STRUCTURAL ANALYSIS

The activities reported within this task include: development of the NASTRAN finite element model, development of the material test plans for design allowables, and the weight history and current status of the ACA.

4.2.1 NASTRAN Model

Based on the selected design concept a NASTRAN three-dimensional Finite Element Model (FEM) of the aileron is being developed. The purpose of the FEM

is to determine internal loads, deflections, and structural influence coefficients (SIC's). The model includes a representation of the actuators. The Lockheed-developed anisotropic quadrilateral membrane element, a linear stress function element, is used to model the surfaces and webs.

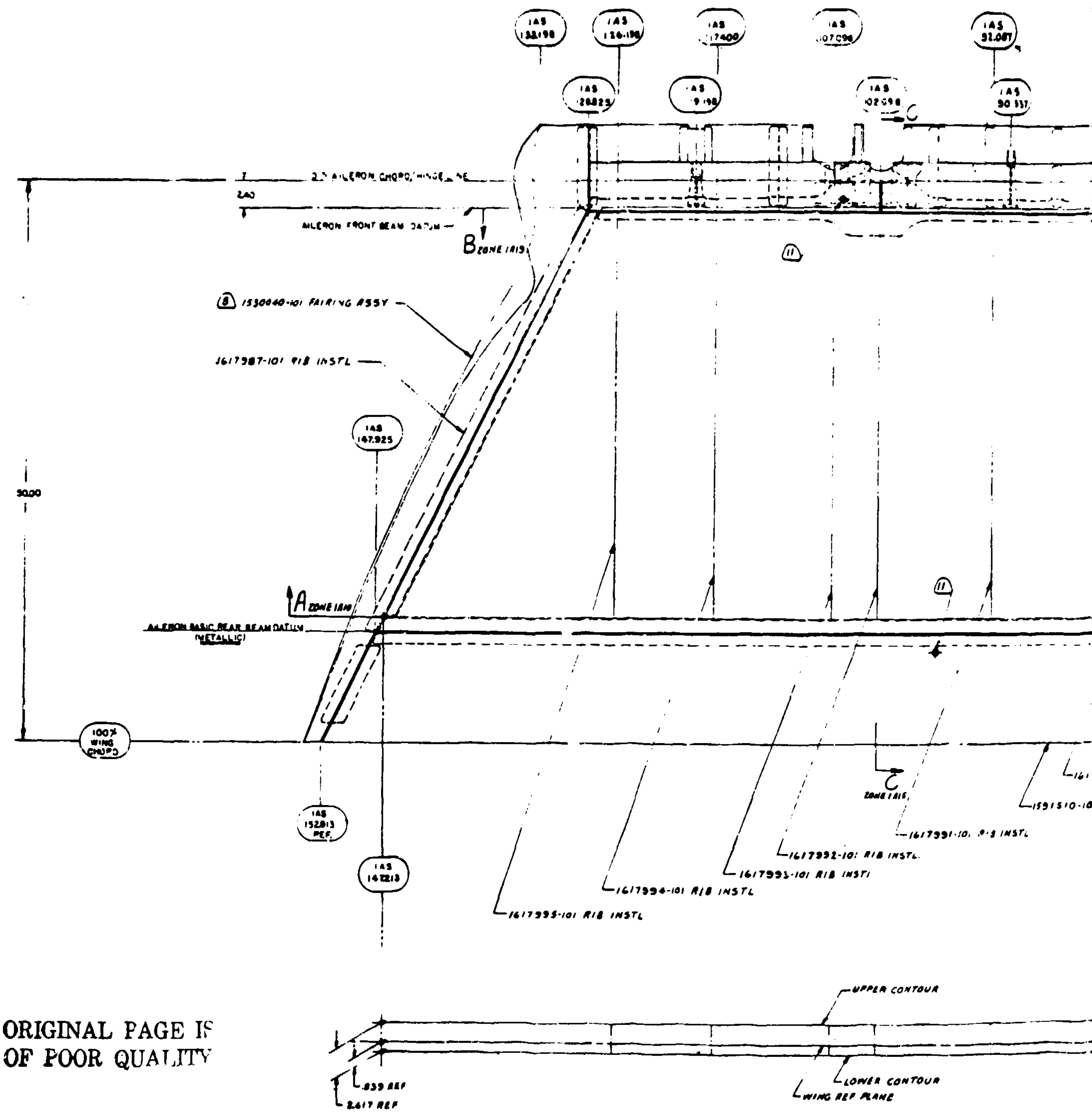
The general layout of the model is shown in Figure 4-2. The models for the actuator and hinges are shown in Figure 4-3. Auxiliary stations at models 1100, 1300, 1700, 2000, 2300 do not include rib panels, or rib caps. They have been included in the model to provide additional detail for the stress pattern in the surfaces.

4.2.2 Development of Material Verification Test Plans

The material evaluation (Task I) led to the selection of preplied T300/5208 graphite/epoxy tape for the covers and spars and T300/5208 24 x 23 x 8HS graphite fabric/epoxy for the ribs. A hybrid of fabric and tape was selected for the main rib caps.

The tape selected for the aileron is 7.5 mils/ply. The unidirectional tape properties, developed as part of Lockheed's Advanced Composite Vertical Fin ACVF Program NASA Contract NAS1-1400, will be used to compute laminate properties.

The ply level properties for T300/5208 24 x 23 x 8HS graphite fabric/epoxy will be developed by tests of 0° and $\pm 45^{\circ}$ fabric laminates. For ply level allowables 30 replicates will be tested at room temperature, dry to establish a sufficient statistical base to compute 'B' basis allowables; 10 replicates each tested at -65°F and 180°F(wet) will establish environmental adjustment factors; and 5 replicates each at fiber volume extremes (outside of specification limits) will determine the effect of high or low fiber volumes on properties. The question of whether the dry or wet state is most critical for a given test mode (tension, compression, or shear) at -65°F will be determined by testing 5 replicates each for both conditions and testing 5 more replicates for the critical state. The results of these tests will be used to develop ply-level allowables for fabric so that



SECTION A-A

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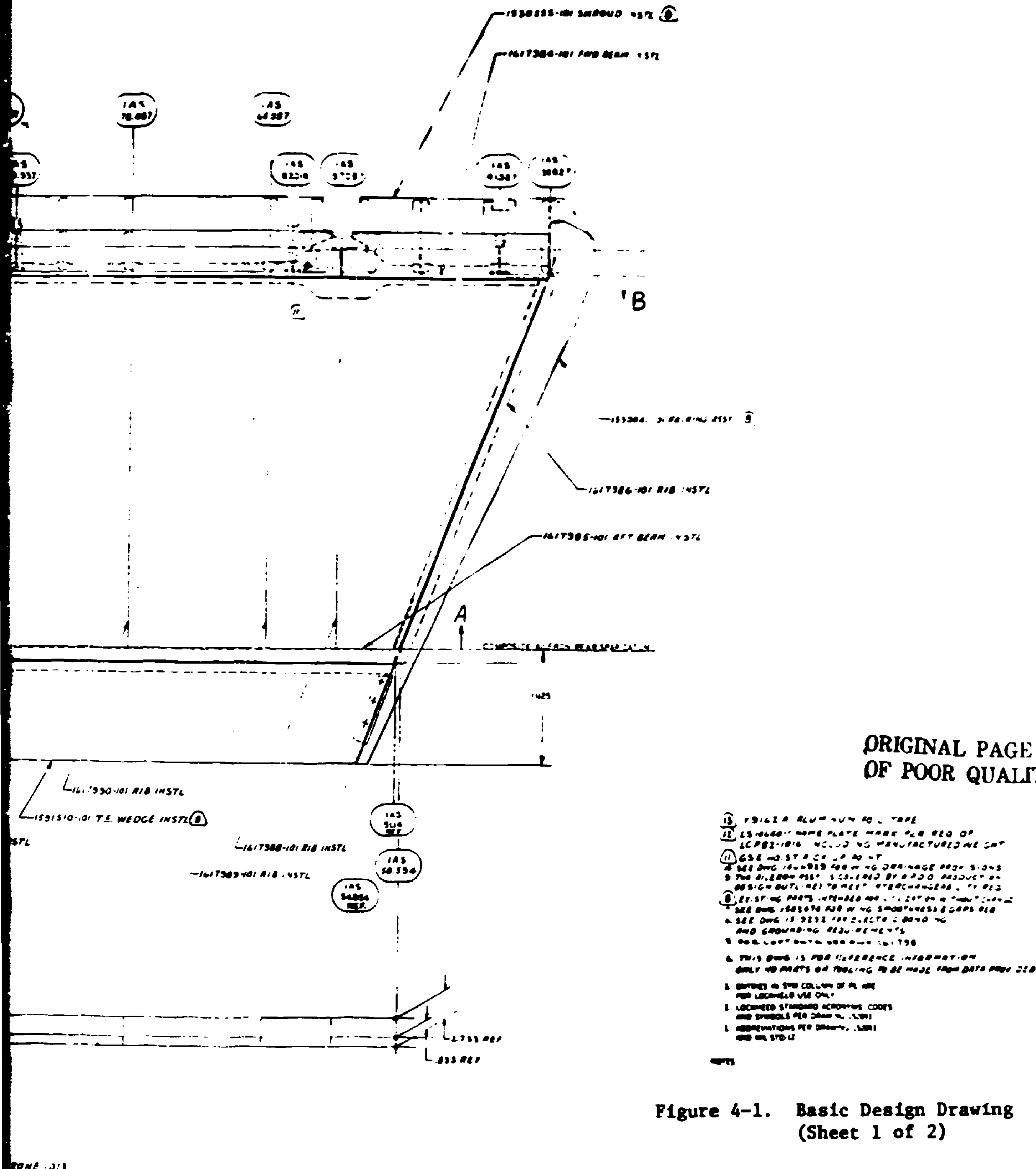

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Figure 4-1. Basic Design Drawing
(Sheet 1 of 2)

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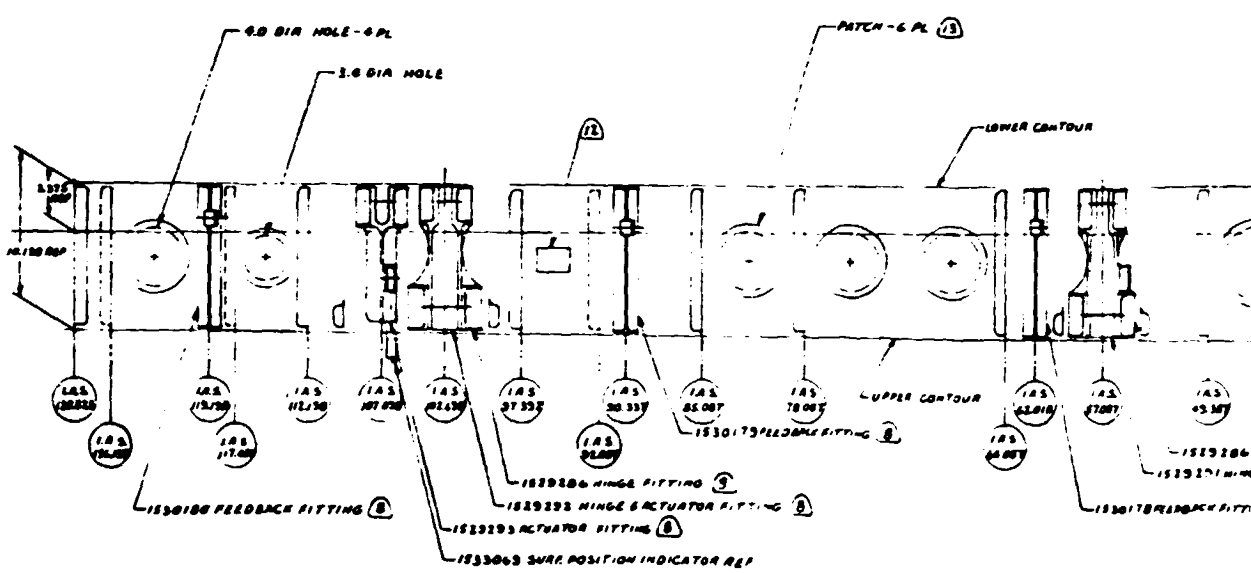

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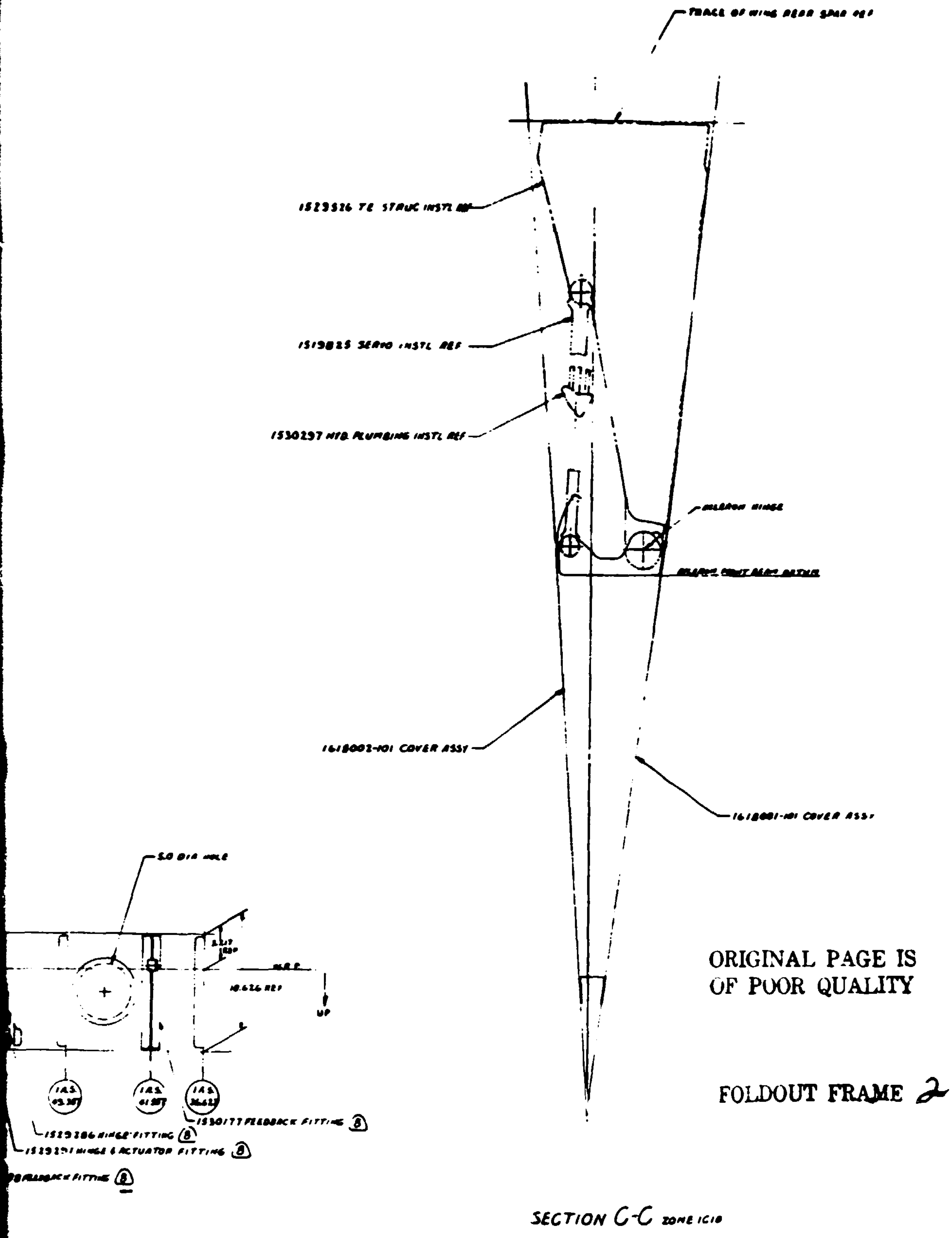

Figure 4-1. Basic Design Drawing
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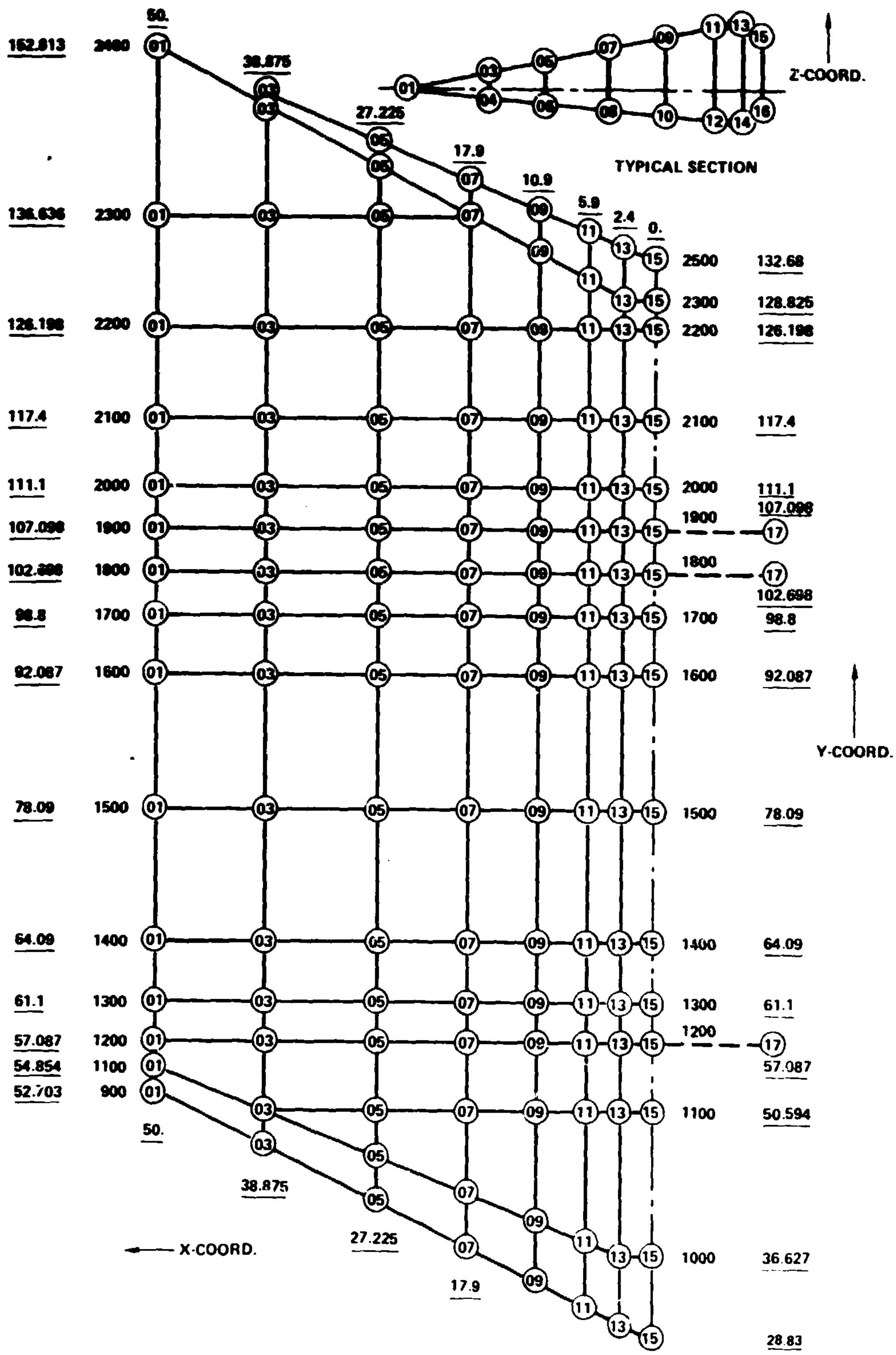

Figure 4-2. Composite Aileron Finite Element Model

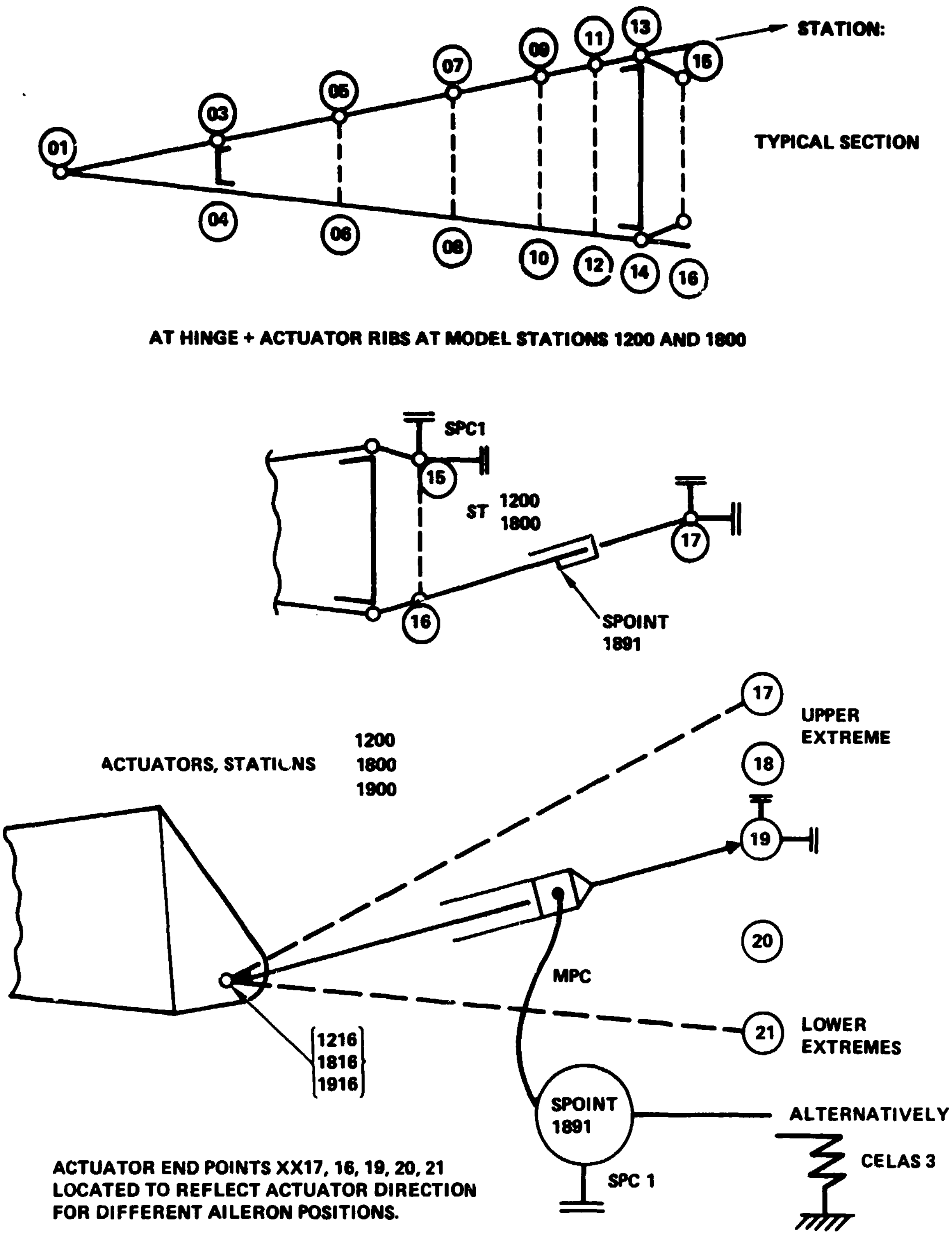

Figure 4-3. Actuator and Hinge Support Stations

unnotched laminate properties can be computed using Lockheed's laminate strength prediction computer program.

Laminate characterization test results will be used to verify the predicted properties for tape, fabric, and hybrid laminates. The "B" basis allowables will be determined for these laminates (using a sample size of 30) with a circular notch. These data will be related to average unnotched laminate properties to obtain adjustment factors for the combined effects of data scatter, notch effects, and environmental effects. The adjustment factors will be determined for tape, fabric, and hybrid laminates. The data determined from the laminated tests for laminate tape will be supplemented by the ACVF tape laminate test results so that a broad range of laminate orientations will be represented.

The detail test plans for the ply-level tests and laminate tests will be presented at a later date in a revised edition of the ancillary test plan.

4.2.3 Weight Status

The current weight status is shown in Table 4-1. A weight saving of 25.5 percent (35.8 pounds including a 5-lb growth allowance) is currently being predicted. Without the growth allowance, a weight saving of 29.1 percent (40.8 pounds) is anticipated. Composite material utilization is currently predicted to be 65.1 percent of the redesigned aileron weight. A summary of weight changes from the previous Quarterly Report will be presented in a format as indicated in Table 4-2. A weight-time history for the composite aileron is provided in Figure 4-4.

4.3 MATERIALS AND PRODUCIBILITY ANALYSIS

Preliminary material specifications have been prepared for the three material forms selected for the ACA:0.0075 in/ply graphite tape prepreg, 24 x 23 x 8HS graphite fabric prepreg, and syntactic epoxy. These specification are as follows:

TABLE 4-1. WEIGHT STATUS REPORT

ITEM	METAL DESIGN TOTAL WEIGHT (LB)	COMPOSITE DESIGN TARGET WEIGHT (LB)	COMPOSITE DESIGN TOTAL WEIGHT (LB)	COMPOSITE DESIGN COMPOSITE MAT'L WT (LB)	WEIGHT CHANGE
Covers	39.3	31.6	28.7	28.7	N
Spars	25.4	20.2	19.2	5.8	O
Ribs	39.3	22.0	20.0	20.0	N
Fairing & Shrouds	16.2	16.2	16.9	-	E
T.E. Wedge Assy	12.6	6.0	6.0	5.6	
Assembly Hardware	4.2	2.9	2.7	-	
Protective Finish	3.4	3.4	3.4	-	
Lightning Protection	-	3.0	2.7	-	
Design Growth Allowance	-	-	5.0	5.0	
Total Aileron Predicted Delivery Weight - Lb/Unit	140.4		104.6	65.1	
Weight Saving - Lb/Unit			35.8		
Percent Weight Saved			25.5%		
Percent Composite Material				62.2%	
Total Aileron Current Indicated Weight - Lb/Unit		105.3	99.6	60.1	
(Predicted Less Growth)			29.1%	60.3%	
Current Indicated Weight of Redesigned Component	111.3 △1		70.5 (36.6% Weight Saved) △2		

Weight Basis: 70% EST, 30% CALC, 0% ACT

△1 Total metal design weight less weight of components not redesigned

△2 Based on redesigned metal components

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TABLE 4-2. SUMMARY OF WEIGHT CHANGES

ITEM	WEIGHT CHANGE (LB)		REMARKS
	TOTAL	COMPOSITE	
Covers	N	N	Initial Issue
Spars	O	O	
Ribs	N	N	
.	E	E	
.			
.			
TOTAL	0	0	

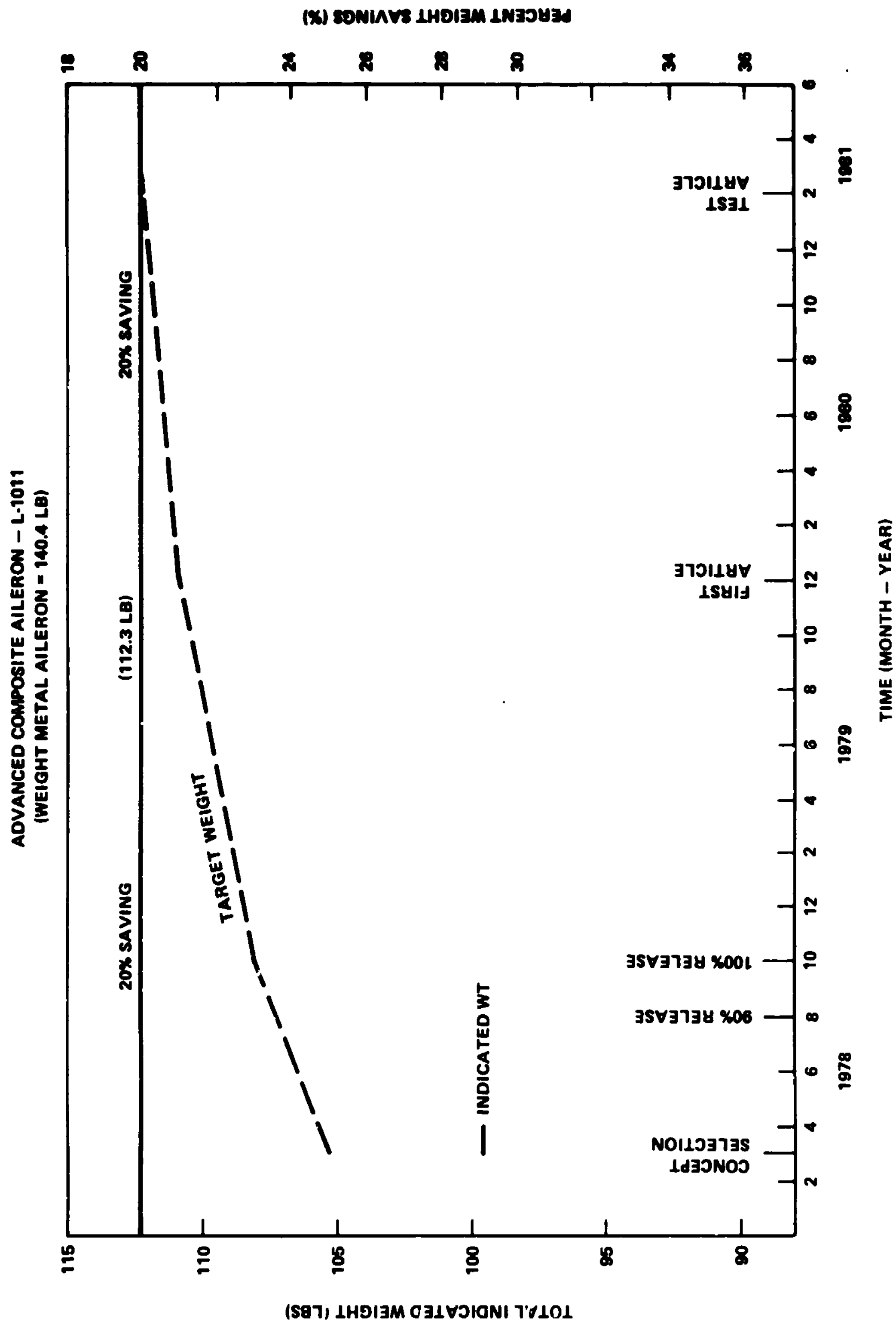

Figure 4-4. Weight Time History

C-22-1379/112	"Graphite Fiber Non-Woven Tape, 350 KSI Strength, 33 MSI Modulus, 350°F Curing. Epoxy Impregnated, Low Resin Content, 7.5 Mils/Ply
C-22-1388 (Basic)	"Graphite Woven Fabric, Resin Impregnated, General Specification for
C-22-1388/11	"Graphite Woven Fabric, 24 x 23 8 Harness Satin Weave, 33 MSI Modulus, 350°F Curing, Epoxy Impregnated
C-28-1387	"Syntactic Epoxy Core Material"

These draft specifications fully define all test requirements and procedures, and define all qualitative and workmanship requirements. The initial batches of material for Task II are being procured to these specifications on a target basis. These batches will be used for qualification tests, after which the specifications will be modified as necessary and formally released.

SECTION 5

TASK II - DESIGN AND ANALYSIS PROCESS DEVELOPMENT AND VERIFICATION

The process development and verification activities for the selected ACA design concept and materials will be conducted by Avco.

5.1 PROCESS DEVELOPMENT

The detail plans for development of the manufacturing processes for the ACA have been completed and are shown in Table 5-1. Process development will be coordinated with design and analysis to verify selection of fabrication procedure.

TABLE 5-1. TEST ITEM 4.1 PROCESS DEVELOPMENT TESTS

COMPONENT	PROCESS OPTIONS		EVENT*	TEST	TOTAL** STRUC. TESTS
Covers - Tape	(1) Prebleed:	Both skins & doublers	3	SBS & Resin %	18
				"C" Stage) - Resin %)	9
	(2) Bleed:	120 Fiberglass between Outer Skins & Aluminum Flame Spray	2	SBS & Resin %	12
	(3) Doubler Interface Study:	Caul Sheet or Vacuum Bag	As Req'd.	Inspection	-
Spars & Ribs (Typical Channel)			FABRIC / TAPE		
	(1) Bagging Procedure:	Rubber Mandrel Various Radii	6 / 6	SBS & Resin %	72
Spars-TAPE	(2) Bleeding	Bleed in Tool	2 / 2	SBS & Resin %	24
		Prebleed	2 / 2	SBS & Resin %	24
Ribs-FABRIC	(3) Lightening Hole Flanges	Press Form	FABRIC & Tape	Inspection	-
Assembly (Upper-Covers)	Fastener Hole Preparation		As Req'd.	Inspection	-

* Quantity shown is minimum required; additional quantities will be made as necessary to meet physical and mechanical properties.

** All tests will consist of three specimens cut from each sample; fastener test excluded.

REFERENCES

1. Griffin, C. F., et al, "Advanced Composite Aileron For L-1011 Transport Aircraft" Quarterly Technical Report #1, LR 28426, 23 January 1978.